Boston University
Graduate School

Thesis
The Rate of Oxidation of Used Crankcase Oils

by
George E. Hall Jr.
(A.B., Clark University, 1937)
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Master of Arts
1941

Acknowledgement

I wish to acknowledge at this time the helpful guidance and ever willing aid and many constructive suggestions given by Dr. E.O. Holmes Jr. in making this research possible.

Approved
by

First Reader. Edward A. Holmes Jr. ....

Second Reader. Chester M. Alter ....

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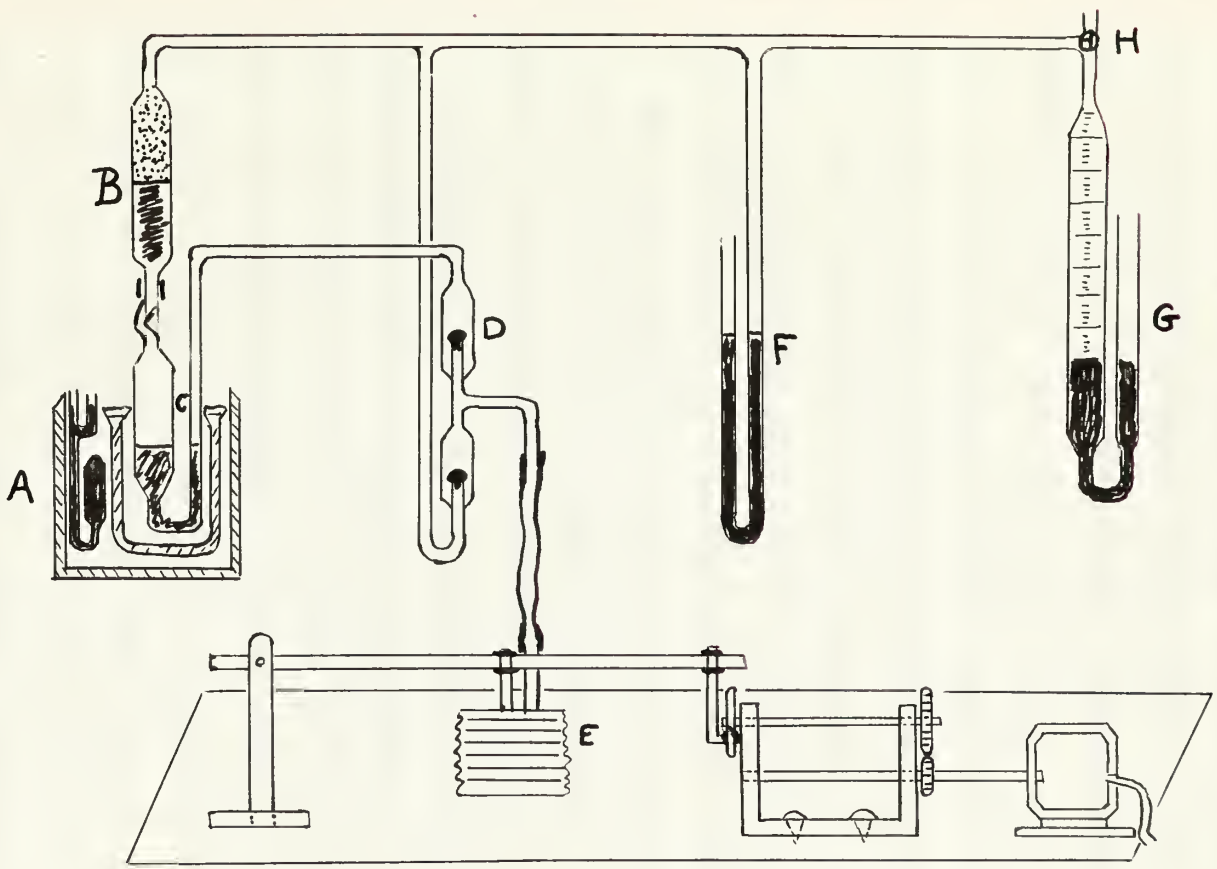
INTRODUCTION

With the foreign situtation as it is today, petroleum is beginning to assume an increasingly important place. One naturally wonders about the potential supply. Present known reserves are sufficient for the immediate future, but the magnitude of the base ~~of the base~~ of demand, now a billion and a third barrels a year has far reaching effects that a continuous supply at low cost is of national interest. Thus only through the wise use of this vital and irreplaceable fluid can this country avoid many of the difficulties that confront other nations.

Recent trends in investigations in the field of petroleum have been the study of the oxidation tendencies (1,2.). Yet all previous investigations have been on unused oils. These studies have been on the stability to oxidation and the nature of the products of oxidation (2). Many methods have been devised for such investigations, as the Indiana Oxidation Test, the Sligh Oxidation Test, and the Oxygen Stability Test. These tests are all used by the large oil refiners, but the method used by Dornte (1) was thought to be superior to all others. The method was essentially to measure the volume of oxygen absorbed per unit of time by a weighed sample of used oil at constant pressure and temperature. The apparatus was designed so that the unused oxygen is recycled through the oil sample.

(1) Dornte - Ind. Eng. Chem. 28,26 (1936)
(2) Fenske - Ind. Eng. Chem. Anal. Ed. 13,51 (1941)

The reason for finding the rate of oxidation of a used sample of oil was because no one had previously investigated this problem. The object of such an investigation would be to determine whether a crankcase oil becomes more or less resistant to oxidation with use.



A - Thermostat
B - Adsorption Chamber
C - Oil Chamber
D - Glass Valves

E - Bellows
F - Manometer
G - Gas Burette
H - Three way StopCock

CONSTRUCTION OF APPARATUS

The apparatus consists of the following essential parts. The oil chamber in which the sample of oil is placed. This consists of a six inch length of twenty-five (25) millimeter glass tubing drawn down at both ends so that five (5) millimeter tubing may be sealed on. Then the absorption chamber which is made of the same size tubing as the oil chamber and in the same manner. In the absorption chamber is placed anhydrous Calcium Sulfate to absorb any moisture and Ascarite to absorb any carbon dioxide given off by the sample of oil. The two substances are placed in the chamber in such a manner that the moisture is absorbed from the unused oxygen first.

The third essential part is the mercury manometer which is made of five (5) millimeter tubing and is constructed so that it is nine hundred (900) millimeters high.

An important part of the apparatus is the pair of glass valves. They are so designed that when one valve is open the other is closed. Perhaps it might be worth mentioning how the valves were designed. A glass tack is made by flatting one end of a five (5) millimeter glass rod and drawing the other and out to the desired size, usually ten (10) millimeters in length. This tack is ground to fit into a piece of five (5) millimeter glass tubing. Then this tubing is sealed into a piece of eight (8) millimeter tubing about two inches long and drawn down to five (5) millimeters on the opposite end. Two such valves were made and then a T-tube was sealed

between them to lead to the intake from the pump.

The bellows, which is used as the pump, is expanded by means of a shaft that leads to a wheel. This wheel is driven by a motor which is geared in such a manner that the speed of the motor will not force the oxygen through the oil at too great a rate. The speed of the motor was also controlled by a rheostat.

A gas burette was used to measure the amount of oxygen absorbed by the sample of oil. This burette was sealed into the apparatus by means of a three way stop-cock. The purpose of the stop-cock was to enable one to fill the burette with oxygen without interrupting a run. The amount of oxygen taken up each half hour was measured over mercury.

The entire apparatus was made of pyrex glass sealed together. Only the oil chamber and the lead from the pump were sealed by means of rubber tubing. The reason for this type of connection was to save the necessity of making a new seal for each run, and no way could be devised to make a glass to copper seal on the lead from the pump to the valves. The apparatus was evacuated, before and after each run, to test for air-tightness in all the seals.

The following precautions were noted while carrying out the investigation and seem worthy of mentioning. The most important factor was to stop the pump in the same position each time. The most suitable position was at the top of a stroke. If this precaution was not taken it led to an error

in reading the amount of oxygen absorbed. It was also necessary to bring the position of the mercury level in the manometer to the inital level for each reading. The adsorption chamber had to be rechanged several times due to the consideral amount of moisture and carbon dioxide given off by the sample of oil. There was also a considerable amount of gasoline absorbed by the Calcium Sulfate and the Ascarite. If the absorption chamber was allowed to remain in the apparatus too long, absorbed gasoline was given back to the system.

PROCEDURE

The procedure in carrying out a run is very simple. The absorption chamber is removed from the apparatus and weighed. Then approximately twenty-five (25) grams of the used oil is placed in the chamber. It is then reweighed accurately to two places and the difference between the two is taken as the weight of the sample. The chamber is then placed in the thermostat, and joined to the apparatus with rubber connections. The system is now evacuated and allowed to stand until the thermostat reaches the temperature of the run-140°C.. Oxygen is now admitted to the system so that the level of the mercury in the manometer shows atmospheric pressure of the oxygen in the system. Care must be taken that too much oxygen is not forced in so as to cause an excess pressure. This excess pressure could lead to an error in the subsequent readings for the run.

The pump is now started and the time noted. The gas burette is also filled with oxygen and the reading recorded. The amount of oxygen absorbed is measured every thirty (30) minutes by stopping the pump at the top of a stroke, so that the chamber will be fully expanded. Oxygen is now admitted to the system by moving the burette up until the mercury in the manometer has been brought back to atmospheric pressure. The gas burette is then closed off from the rest of the system, and the reading recorded in the note book. The difference

between this reading and the previous reading being taken as the amount of oxygen absorbed for the thirty (30) minute period. This procedure is repeated for a period of six hours. This time was established by a series of perliminary runs.

After a complete rin the system is evacuated again and allowed to stand for several hours. The purpose in evacuating before and after was to test for any leaks that may have developed in the apparatus, also to evacuate any gasoline vapors that may be present in the system. The barometeric pressure was recorded before and after a complete run, the average being taken as the pressure of a single run. The apparatus was standardized by running an unused oil under the same conditions as previously stated.

The oil chamber, stained a dark color during the run, was cleansed in the following manner. It was washed several times with benzene, and then with ethyl alcohol, and finally with ether. After washing with ether, the chamber was allowed to dry before refilling for another run.

No attempt was made to make an analysis of the oxidized oil to learn the products of oxidation. We assumed as did Dornte (1) assumed that no appreciable carbon monoxide or hydrogen were produced during a single run. Runs I-XI were made on used oils. Runs XIV and XVI were with sample B-9 with either a 0.01% of Diphenyl Amine or a 0.01% Hydroquinone to determine the action of inhibitors on the rate of oxidation.

(1) Dornte - Ind. Eng. Chem. 28,26 (1936)

Run I
Sample B-1

Quaker State #40 - 4,610 miles

Weight of Sample - 26.83 grams

Barometeric Pressure - 755.5 mm.

Temperature of Air - 25°C

Temperature of Oil - 140°C

Actual Data		Conversion to 100g. at S.T.P.	
Time	O_2 Absorbed	Time	O_2 Absorbed
30 min.	8.3 cc.	30 min.	28.18 cc.
60 "	13.6 "	60 "	46.17 "
90 "	16.9 "	90 "	57.38 "
120 "	21.5 "	120 "	73.00 "
150 "	26.9 "	150 "	91.35 "
180 "	30.9 "	180 "	104 .96 "
210 "	36.0 "	210 "	122.23 "
240 "	40.9 "	240 "	138.83 "
270 "	43.9 "	270 "	149.07 "
300 "	48.0 "	300 "	162.97 "
330 "	52.7 "	330 "	178.93 "
360 "	56.5 "	360 "	191.85 "

Run II
Sample B-2

Kendall #30 - 3,500 miles

Weight of Sample - 27.3 grams

Barometeric Pressure - 765 mm.

Temperature of air - 25°C

Temperature of Oil - 140°C

Actual Data		Conversion to 100g. at S.T.P.	
Time	O_2 Absorbed	Time	O_2 Absorbed
30 min.	16.6 cc.	30 min.	55.90 cc.
60 "	23.8 "	60 "	80.15 "
90 "	32.1 "	90 "	108.10 "
120 "	41.1 "	120 "	138.40 "
150 "	46.0 "	150 "	154.90 "
180 "	51.4 "	180 "	173.10 "
210 "	56.4 "	210 "	189.90 "
240 "	61.5 "	240 "	207.05 "
270 "	66.4 "	270 "	223.55 "
300 "	71.2 "	300 "	239.70 "

Run III
Sample B-3

Kendall #20W - 1,575 miles

Weight of Sample - 23.72 grams

Barometeric Pressure - 764 mm.

Temperature of Air - 24°C

Temperature of Oil - 140°C

Actual Data		Conversion to 100g. at S.T.P.	
Time	O_2 Absorbed	Time	O_2 Absorbed
30 min.	8.20 cc.	30 min.	31.86 cc.
60 "	16.55 "	60 "	64.31 "
90 "	20.65 "	90 "	80.25 "
120 "	25.35 "	120 "	98.53 "
150 "	31.35 "	150 "	121.83 "
180 "	38.95 "	180 "	151.37 "
210 "	45.55 "	210 "	177.00 "
240 "	49.45 "	240 "	192.15 "
270 "	51.85 "	270 "	201.47 "
300 "	54.35 "	300 "	211.20 "
330 "	56.85 "	330 "	220.90 "
360 "	56.85 "	360 "	220.90 "
390 "	57.35 "	390 "	222.90 "
420 "	61.25 "	420 "	238.05 "
450 "	61.25 "	450 "	238.05 "
480 "	63.35 "	480 "	245.55 "

Run IV
Sample B-4

Quaker State #40 - 4,700 miles

Weight of Sample - 28.34 grams

Barometeric Pressure - 769 mm.

Temperature of Air - 25°C

Temperature of Oil - 140°C

Actual Data		Conversion to 100g. at S.T.P.	
Time	O_2 Absorbed	Time	O_2 Absorbed
30 min.	13.4 cc.	30 min.	42.86 cc.
60 "	25.4 "	60 "	83.81 "
90 "	33.1 "	90 "	108.32 "
120 "	36.0 "	120 "	117.80 "
150 "	38.6 "	150 "	129.27 "
180 "	44.4 "	180 "	145.63 "
210 "	50.6 "	210 "	165.27 "
240 "	59.0 "	240 "	197.60 "
270 "	64.4 "	270 "	210.80 "
300 "	67.6 "	300 "	221.20 "
330 "	72.2 "	330 "	236.25 "
360 "	76.2 "	360 "	249.05 "

Run V
Sample B-5

Kendall #40 - 4,434 miles

Weight of Sample - 24.12 grams

Barometeric Pressure - 764.5 mm.

Temperature of Air - 26°C

Temperature of Oil - 140°C

Actual Data		Conversion to 100g. at S.T.P.	
Time	O_2 Absorbed	Time	O_2 Absorbed
30 min.	9.3 cc.	30 min.	35.40 cc.
60 "	20.0 "	60 "	76.11 "
90 "	27.6 "	90 "	105.03 "
120 "	33.6 "	120 "	127.83 "
150 "	37.8 "	150 "	143.90 "
180 "	42.2 "	180 "	160.65 "
210 "	48.4 "	210 "	184.20 "
240 "	51.9 "	240 "	197.55 "
270 "	56.0 "	270 "	213.15 "
300 "	58.3 "	300 "	221.93 "
330 "	64.2 "	330 "	244.35 "
360 "	68.2 "	360 "	259.60 "

Run VI
Sample B-6

Kendall #30 - 2,825 miles

Weight of Sample - 26.67 grams

Barometeric Pressure - 753.5 mm.

Temperature of Air - 25°C

Temperature of Oil - 140°C

Actual Data		Conversion to 100g. at S.T.P.	
Time	O_2 Absorbed	Time	O_2 Absorbed
30 min.	14.7 cc.	30 min.	50.07 cc.
60 "	21.1 "	60 "	71.89 "
90 "	27.1 "	90 "	92.32 "
120 "	33.7 "	120 "	114.80 "
150 "	38.1 "	150 "	129.75 "
180 "	40.3 "	180 "	137.28 "
210 "	44.8 "	210 "	152.63 "
240 "	46.8 "	240 "	159.40 "
270 "	51.4 "	270 "	175.13 "
300 "	54.9 "	300 "	187.05 "
330 "	59.4 "	330 "	202.35 "
360 "	63.0 "	360 "	214.60 "

Run VII
Sample B-7

Kendall #30 - 1,772 miles

Weight of Sample - 28.15 grams

Barometeric Pressure - 767 mm.

Temperature of Air - 26°C

Temperature of Oil - 140°C

Actual Data		Conversion to 100g. at S.T.P.	
Time	O_2 Absorbed	Time	O_2 Absorbed
30 min.	16.0 cc.	30 min.	52.36 cc.
60 "	24.8 "	60 "	81.17 "
90 "	31.2 "	90 "	102.12 "
120 "	38.0 "	120 "	124.38 "
150 "	42.9 "	150 "	140.23 "
180 "	46.0 "	180 "	150.57 "
210 "	49.4 "	210 "	161.70 "
240 "	54.7 "	240 "	179.00 "
270 "	57.5 "	270 "	188.17 "
300 "	61.6 "	300 "	201.60 "
330 "	67.6 "	330 "	221.20 "
360 "	73.0 "	360 "	238.85 "

Run VIII
Sample B-8

Kendall #20W - 3,300 miles

Weight of Sample - 28.15 grams

Barometeric Pressure - 753.5 mm.

Temperature of Air - 25°C

Temperature of Oil - 140°C

Actual Data		Conversion to 100g. at S.T.P.	
Time	O_2 Absorbed	Time	O_2 Absorbed
30 min.	13.6 cc.	30 min.	43.87 cc.
60 "	24.0 "	60 "	77.43 "
90 "	30.0 "	90 "	96.79 "
120 "	36.3 "	120 "	117.10 "
150 "	41.7 "	150 "	134.53 "
180 "	47.1 "	180 "	151.97 "
210 "	53.7 "	210 "	173.30 "
240 "	60.2 "	240 "	194.23 "
270 "	66.0 "	270 "	212.93 "
300 "	70.6 "	300 "	227.93 "
330 "	76.1 "	330 "	245.50 "
360 "	80.3 "	360 "	259.05 "

Run IX
Sample B-9

Kendall #30 - 3,000 miles

Weight of Sample - 26.15 grams

Barometeric Pressure - 765 mm.

Temperature of Air - 25°C

Temperature of Oil - 140°C

Actual Data		Conversion to 100g. at S.T.P.	
Time	O_2 Absorbed	Time	O_2 Absorbed
30 min.	16.7 cc.	30 min.	58.83 cc.
60 "	28.4 "	60 "	100.10 "
90 "	33.8 "	90 "	119.12 "
120 "	43.8 "	120 "	154.40 "
150 "	52.1 "	150 "	183.55 "
180 "	58.3 "	180 "	205.47 "
210 "	65.5 "	210 "	230.85 "
240 "	69.6 "	240 "	245.30 "
270 "	77.0 "	270 "	271.40 "
300 "	84.3 "	300 "	297.10 "
330 "	92.8 "	330 "	327.10 "
360 "	99.4 "	360 "	350.40 "

Run X
Sample B-10

Kendall #30 - 2,900 miles

Weight of Sample - 23.86 grams

Barometeric Pressure - 761 mm.

Temperature of Air - 24°C

Temperature of Oil - 140°C

Actual Data		Conversion to 100g. at S.T.P.	
Time	O_2 Absorbed	Time	O_2 Absorbed
30 min.	16.6 cc.	30 min.	64.04 cc.
60 "	28.8 "	60 "	111.12 "
90 "	39.2 "	90 "	151.25 "
120 "	49.2 "	120 "	185.50 "
150 "	57.4 "	150 "	221.45 "
180 "	62.8 "	180 "	242.35 "
210 "	66.1 "	210 "	255.05 "
240 "	73.8 "	240 "	284.80 "
270 "	80.8 "	270 "	311.70 "
300 "	86.1 "	300 "	332.20 "
330 "	89.1 "	330 "	343.80 "
360 "	95.0 "	360 "	366.50 "

Run XI
Sample B-11

Kendall #30 & #40 -- 5,115 miles

Weight of Sample - 27.79 grams

Barometeric Pressure - 753 mm.

Temperature of Air - 25°C

Temperature of Oil - 140°C

Actual Data		Conversion to 100g. at S.T.P.	
Time	O_2 Absorbed	Time	O_2 Absorbed
30 min.	21.6 cc.	30 min.	70.58 cc.
60 "	33.1 "	60 "	108.15 "
90 "	43.1 "	90 "	140.86 "
120 "	47.2 "	120 "	154.20 "
150 "	54.6 "	150 "	178.40 "
180 "	61.8 "	180 "	201.93 "
210 "	66.6 "	210 "	217.60 "
240 "	73.1 "	240 "	238.80 "
270 "	78.7 "	270 "	251.30 "
300 "	85.6 "	300 "	279.70 "
330 "	91.5 "	330 "	298.95 "
360 "	93.0 "	360 "	303.90 "

Run XII

Kendall #30 - New Oil

Weight of Sample - 24.68 grams

Barometeric Pressure - 757 mm.

Temperature of Air - 26°C

Temperature of Oil - 140°C

Actual Data		Conversion to 100g. at S.T.P.	
Time	O_2 Absorbed	Time	O_2 Absorbed
30 min.	1.3 cc.	30 min.	4.79 cc.
60 "	5.0 "	60 "	18.44 "
90 "	8.5 "	90 "	31.33 "
120 "	8.5 "	120 "	31.33 "
150 "	9.5 "	150 "	35.02 "
180 "	10.5 "	180 "	38.71 "
210 "	12.8 "	210 "	47.19 "
240 "	16.6 "	240 "	61.20 "
270 "	18.2 "	270 "	67.10 "
300 "	20.6 "	300 "	75.95 "
330 "	22.6 "	330 "	83.32 "
360 "	24.7 "	360 "	91.06 "

Run XIII

Kendall #40 - New Oil

Weight of Sample - 23.04 grams

Barometeric Pressure - 765.5mm.

Temperature of Air - 24°C

Temperature of Oil - 140°C

Actual Data		Conversion to 100g. at S.T.P .	
Time	O_2 Absorbed	Time	O_2 Absorbed
30 min.	1.7 cc.	30 min.	6.83 cc.
60 "	2.8 "	60 "	11.27 "
90 "	3.6 "	90 "	14.47 "
120 "	5.8 "	120 "	23.32 "
150 "	7.7 "	150 "	30.95 "
180 "	7.7 "	180 "	30.95 "
210 "	10.2 "	210 "	41.01 "
240 "	11.8 "	240 "	47.45 "
270 "	12.6 "	270 "	50.66 "
300 "	15.8 "	300 "	63.53 "
330 "	16.6 "	330 "	66.75 "
360 "	16.9 "	360 "	67.94 "

Run XIV

Kendall #30 - 3,000 miles with .025 grams of Hydroquinone

Weight of Sample - 25.63 grams

Barometeric Pressure - 763 mm.

Temperature of Air - 26°C

Temperature of Oil - 140°C

Actual Data		Conversion tc 100g. at S.T.P.	
Time	O_2 Absorbed	Time	O_2 Absorbed
30 min.	16.2 cc.	30 min.	56.64 cc.
60 "	31.8 "	60 "	111.18 "
90 "	44.2 "	90 "	154.53 "
120 "	56.9 "	120 "	198.90 "
150 "	64.1 "	150 "	224.15 "
180 "	71.8 "	180 "	251.00 "
210 "	82.6 "	210 "	288.80 "
240 "	85.4 "	240 "	298.60 "
270 "	94.0 "	270 "	328.60 "
300 "	103.2 "	300 "	360.75 "
330 "	112.4 "	330 "	392.90 "
360 "	117.7 "	360 "	411.60 "

Run XV

Quaker State - New Oil

Weight of Sample - 23.99 grams

Barometeric Pressure - 765.5 mm.

Temperature of Air - 26°C

Temperature of Oil - 140°C

Actual Data		Conversion to 100g. at S.T.P.	
Time	O_2 Absorbed	Time	O_2 Absorbed
30 min.	2.1 cc.	30 min.	8.05 cc.
60 "	3.3 "	60 "	12.37 "
90 "	6.2 "	90 "	23.77 "
120 "	9.7 "	120 "	37.20 "
150 "	9.7 "	150 "	37.20 "
180 "	12.6 "	180 "	48.32 "
210 "	15.0 "	210 "	57.51 "
240 "	15.9 "	240 "	60.97 "
270 "	17.5 "	270 "	67.10 "
300 "	22.7 "	300 "	87.05 "
330 "	25.2 "	330 "	96.63 "
360 "	29.2 "	360 "	111.98 "

Run XVI

Kendall #30 - 3,000 miles with .043 grams of Diphenyl Amine

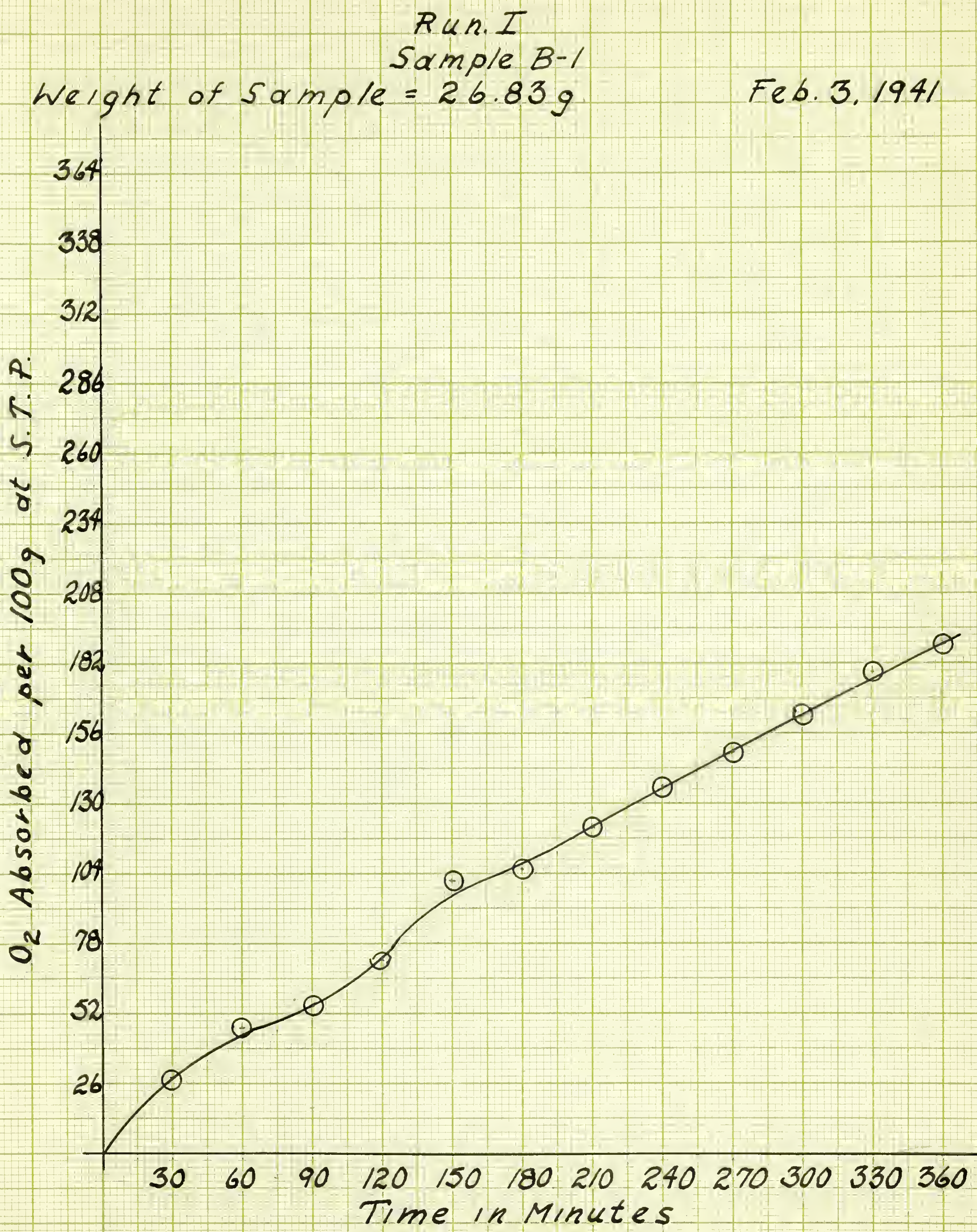
Weight of Sample - 23.24 grams

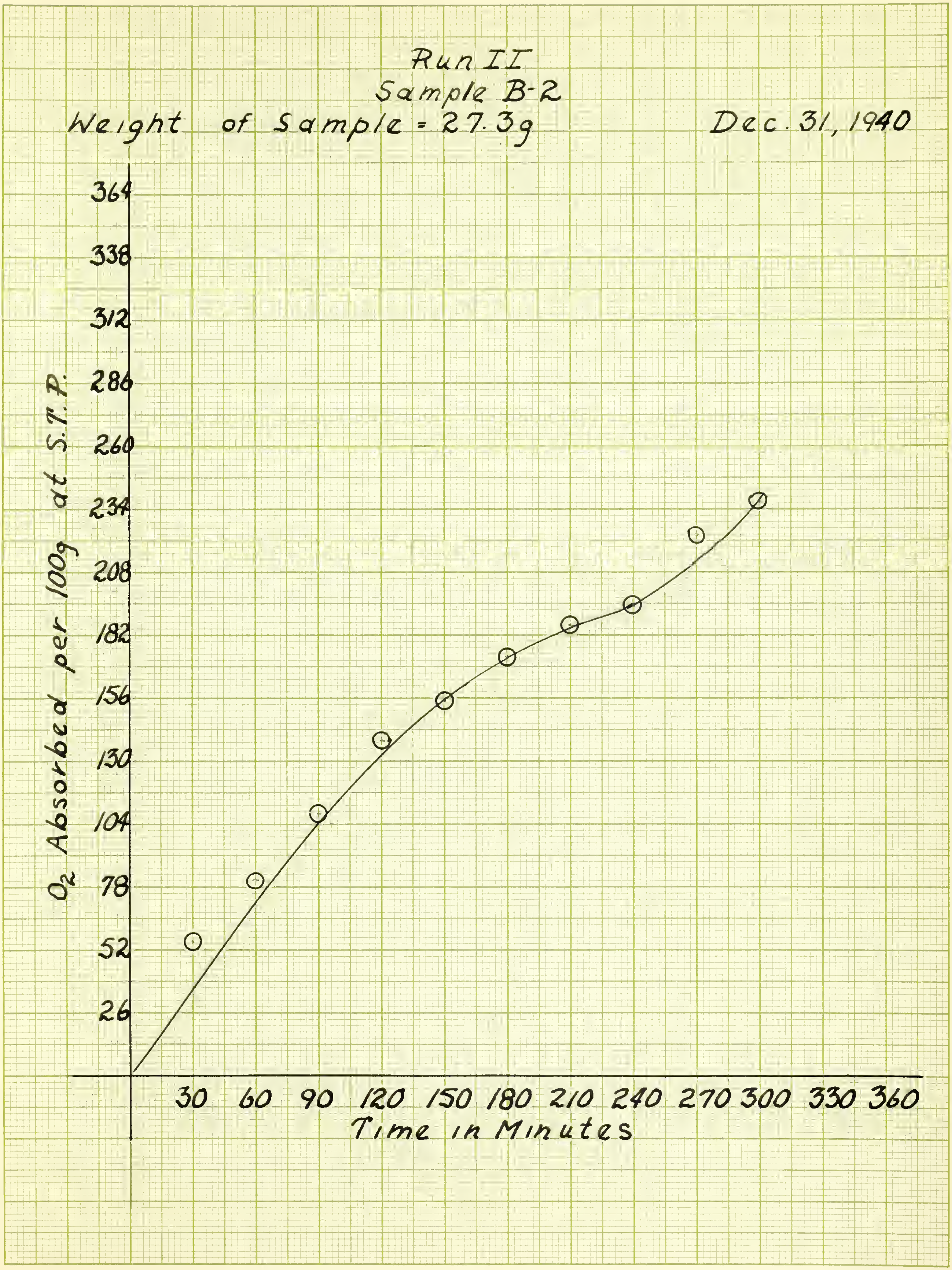
Barometeric Pressure - 769 mm.

Temperature of Air - $25^{o}C$

Temperature of Oil - $140^{o}C$

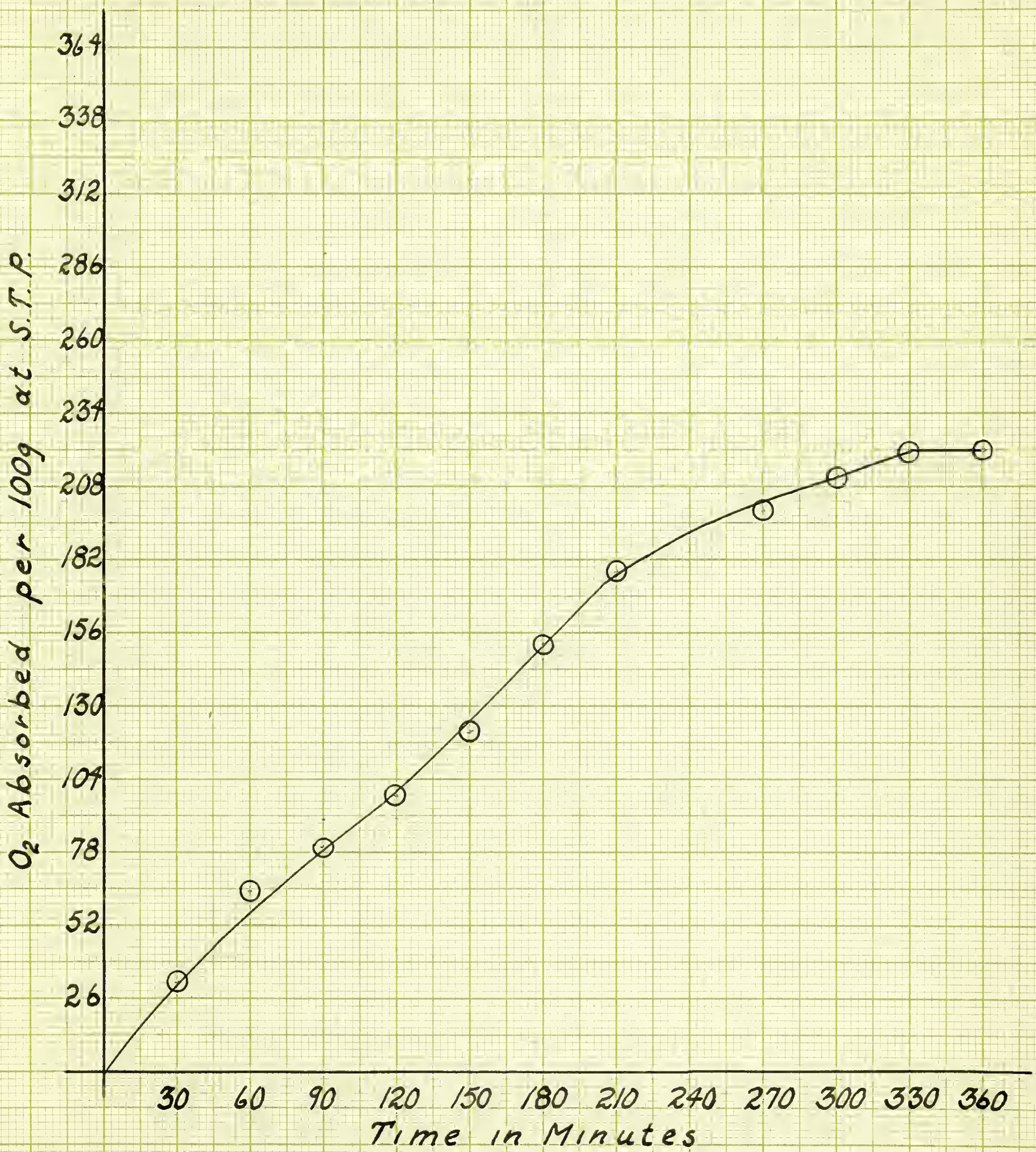
Actual Data		Conversion to 100g. at S.T.P.	
Time	O_2 Absorbed	Time	O_2 Absorbed
30 min.	19.6 cc.	30 min.	78.21 cc.
60 "	31.4 "	60 "	125.30 "
90 "	43.2 "	90 "	172.40 "
120 "	53.0 "	120 "	211.50 "
150 "	62.6 "	150 "	249.80 "
180 "	70.8 "	180 "	282.50 "
210 "	78.7 "	210 "	314.10 "
240 "	85.2 "	240 "	339.90 "
270 "	91.0 "	270 "	363.10 "
300 "	98.2 "	300 "	391.80 "
330 "	103.2 "	330 "	411.80 "
360 "	109.0 "	360 "	434.90 "

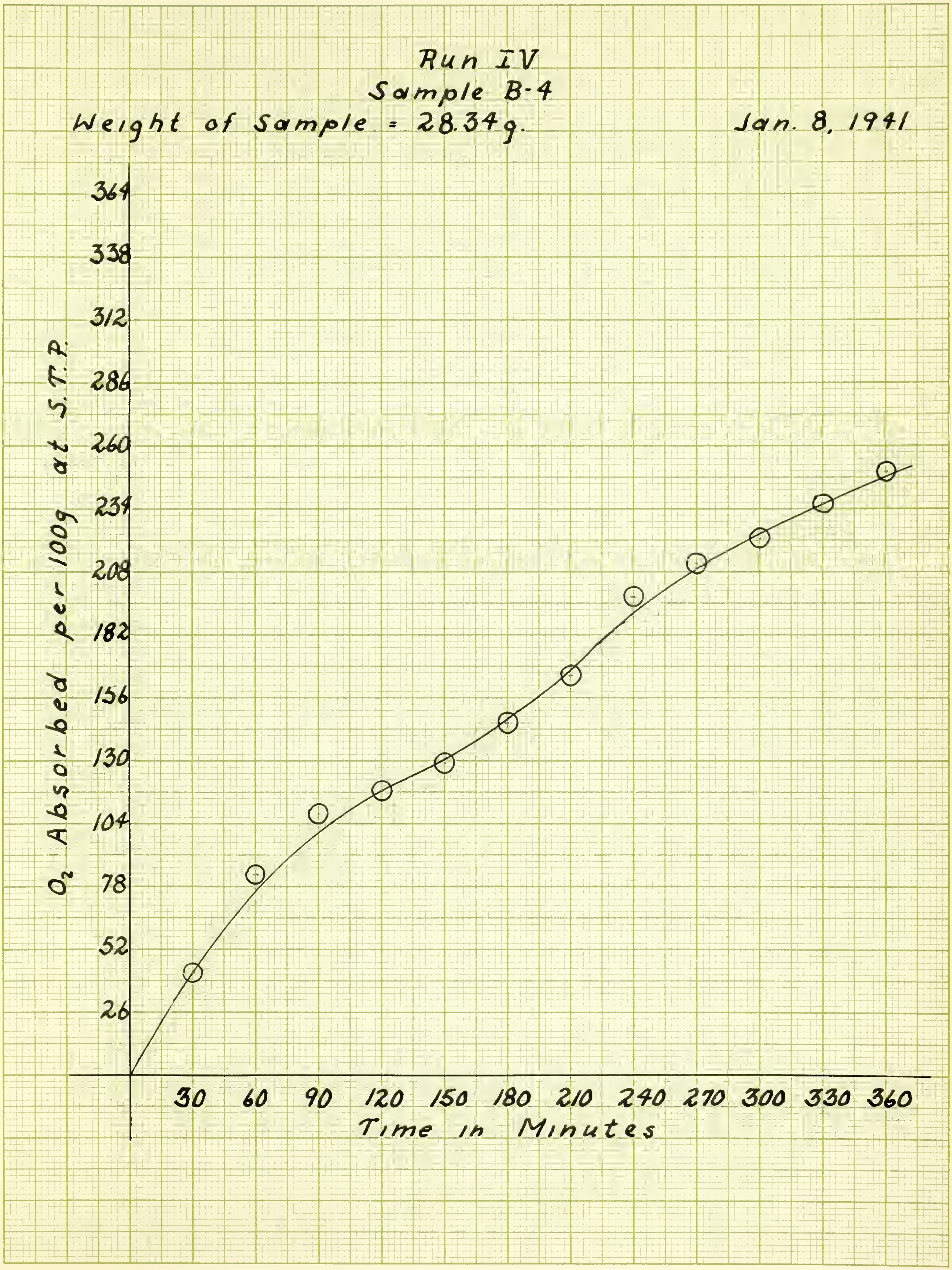

Run. I
Sample B-1
Weight of Sample = 26.83 g
Feb. 3, 1941
O_2 Absorbed per 100g at S.T.P.
364
338
312
286
260
234
208
182
156
130
104
78
52
26
30 60 90 120 150 180 210 240 270 300 330 360
Time in Minutes



Run II
Sample B-2
Weight of Sample = 27.3g
Dec. 31, 1940
O_2 Absorbed per 100g at S.T.P.
364
338
312
286
260
234
208
182
156
130
104
78
52
26
30
60
90
120
150
180
210
240
270
300
330
360
Time in Minutes

Run III
Sample B-3
Weight of Sample = 23.72g Jan. 4, 1941

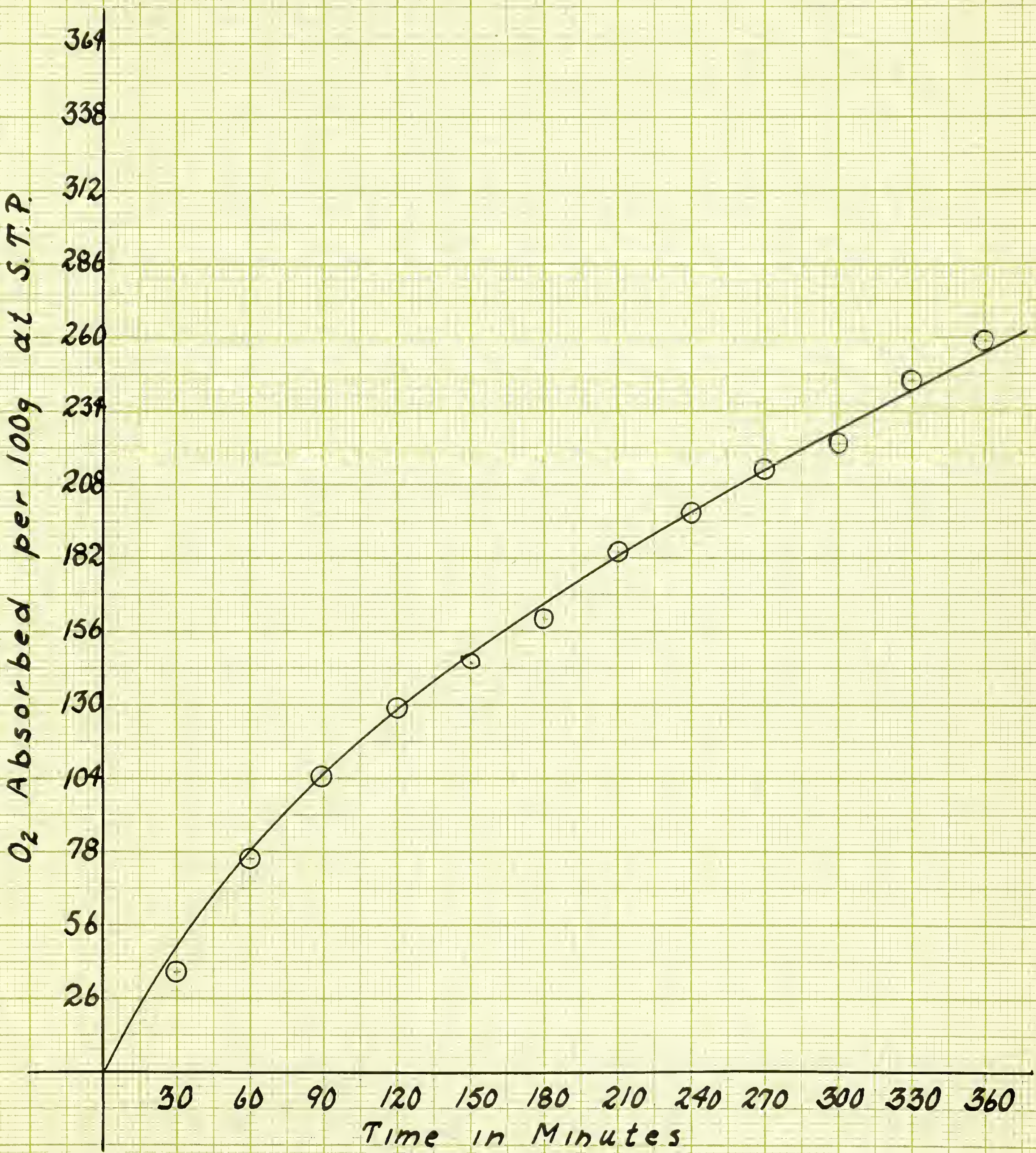


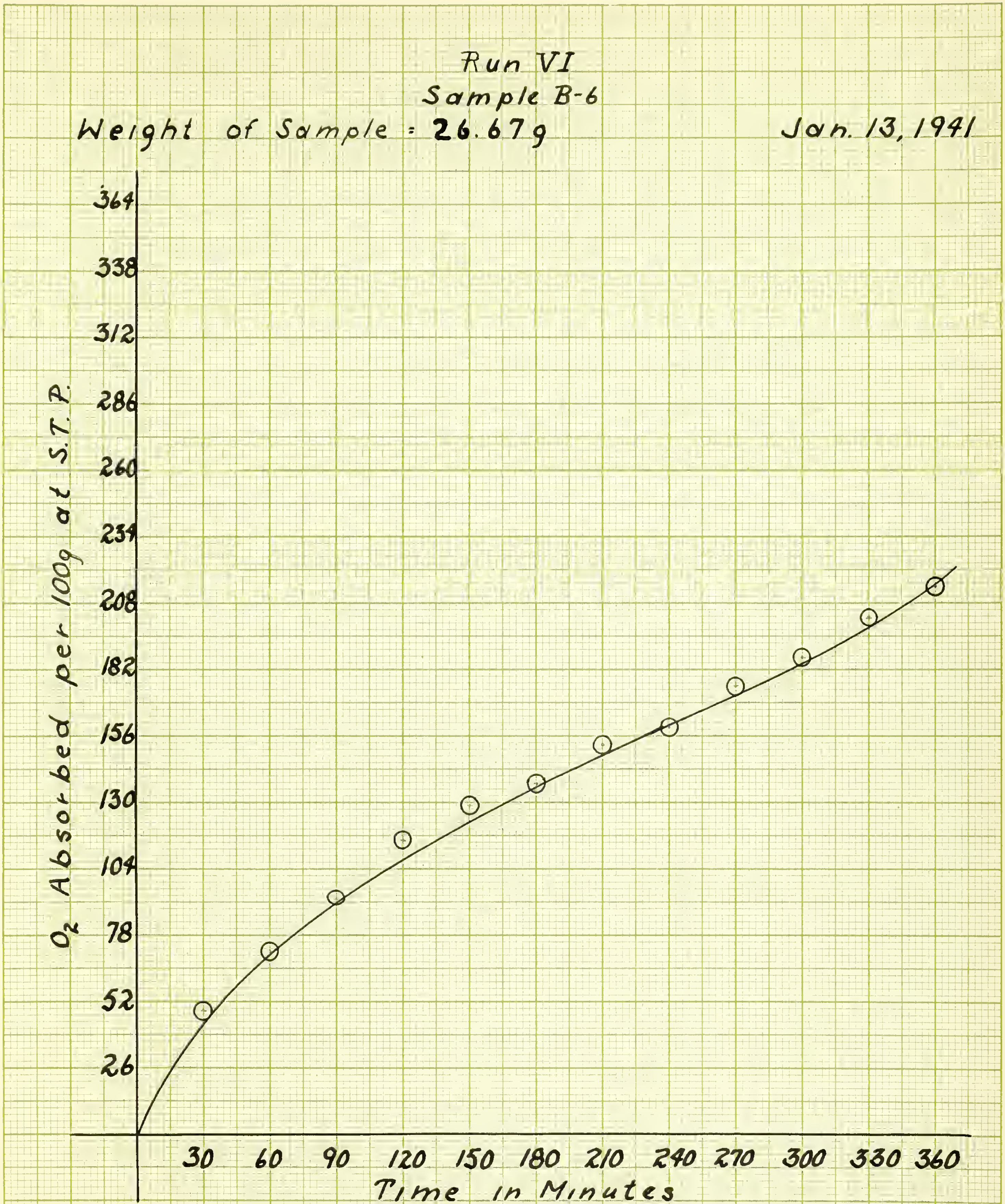

Run IV
Sample B-4
Weight of Sample = 28.34 g.
Jan. 8, 1941
O_2 Absorbed per 100g at S.T.P.
364
338
312
286
260
234
208
182
156
130
104
78
52
26
30
60
90
120
150
180
210
240
270
300
330
360
Time in Minutes

Run V

Sample B-5

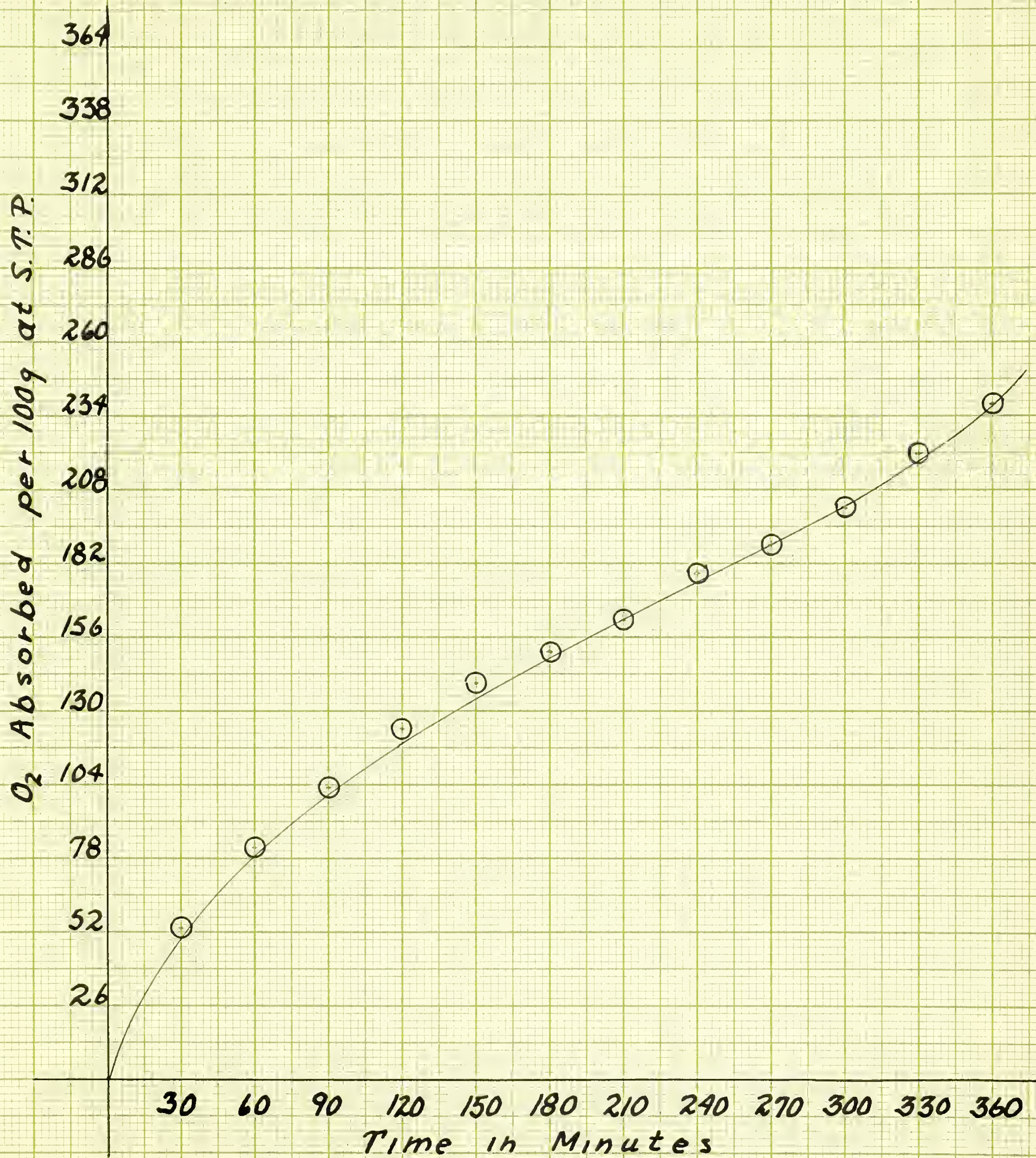
Weight of Sample = 24.12g Jan. 10, 1941



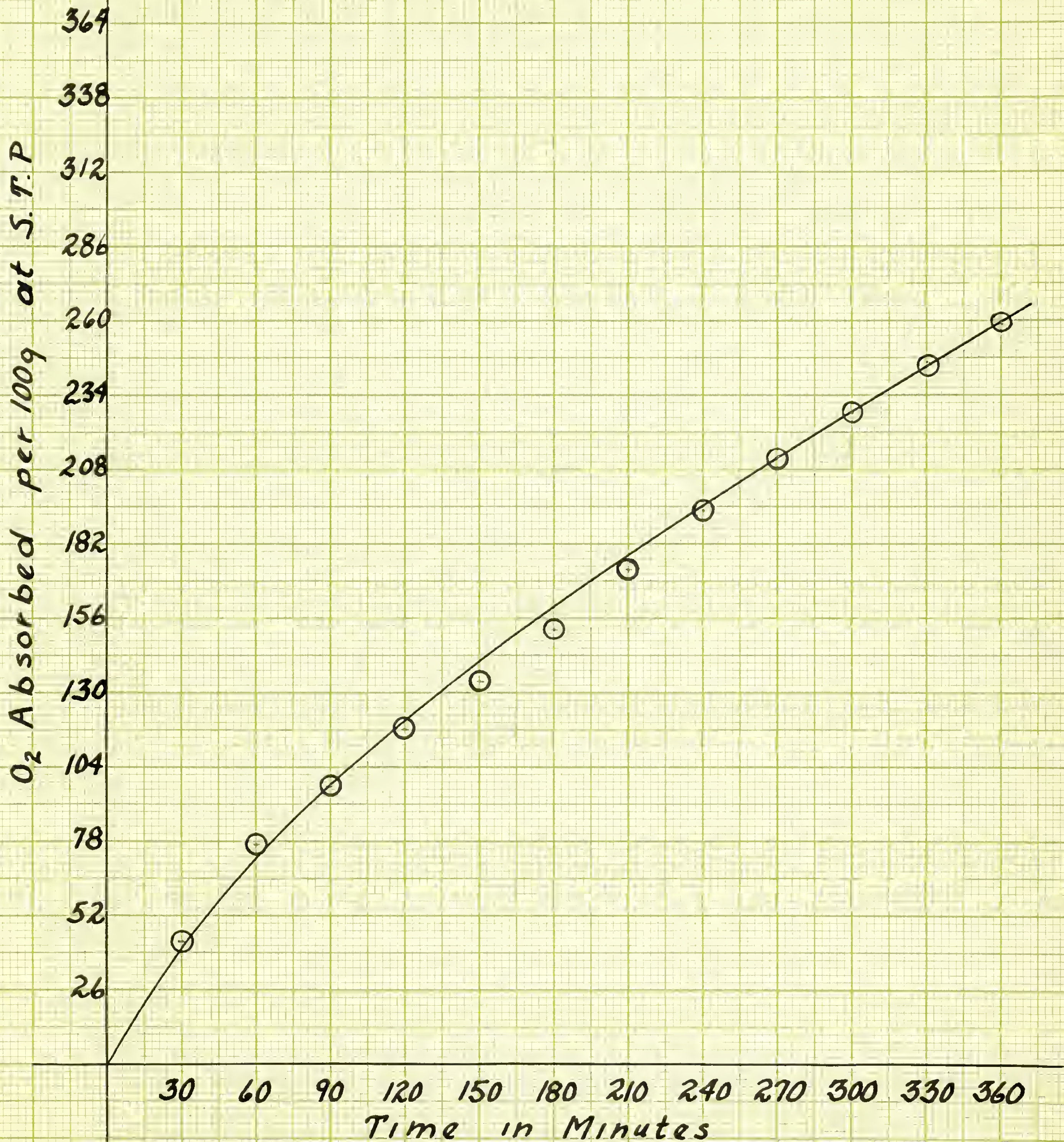

Run VI
Sample B-6
Weight of Sample = 26.67 g
Jan. 13, 1941
364
338
312
286
260
234
208
182
156
130
104
78
52
26
O_2 Absorbed per 100g at S.T.P.
30
60
90
120
150
180
210
240
270
300
330
360
Time in Minutes

Run VII
Sample B-7
Weight of Sample = 28.15g

Jan 15, 1941

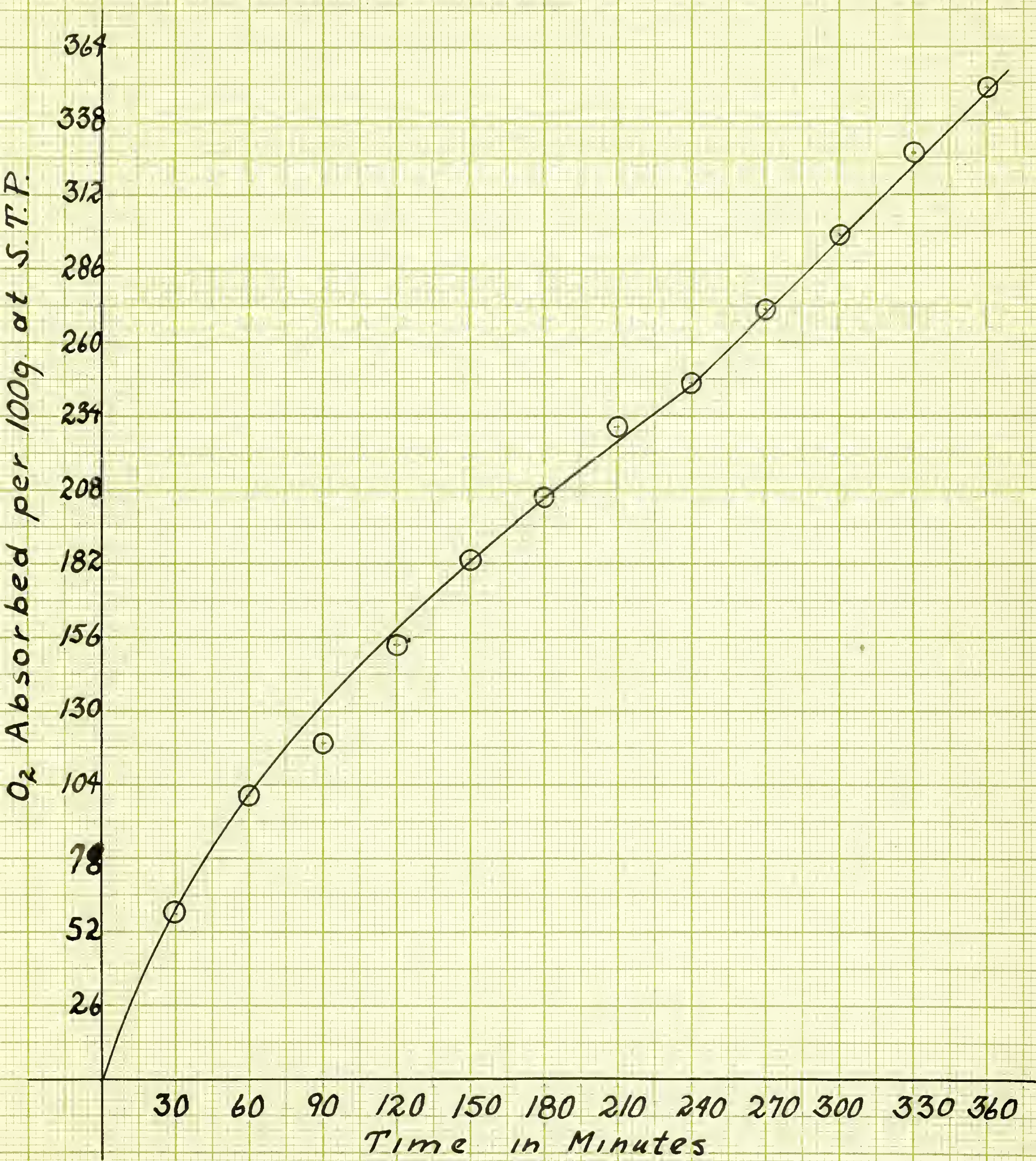


Run VIII
Sample B-8
Weight of Sample = 28.15 g.
Jan. 17, 1941

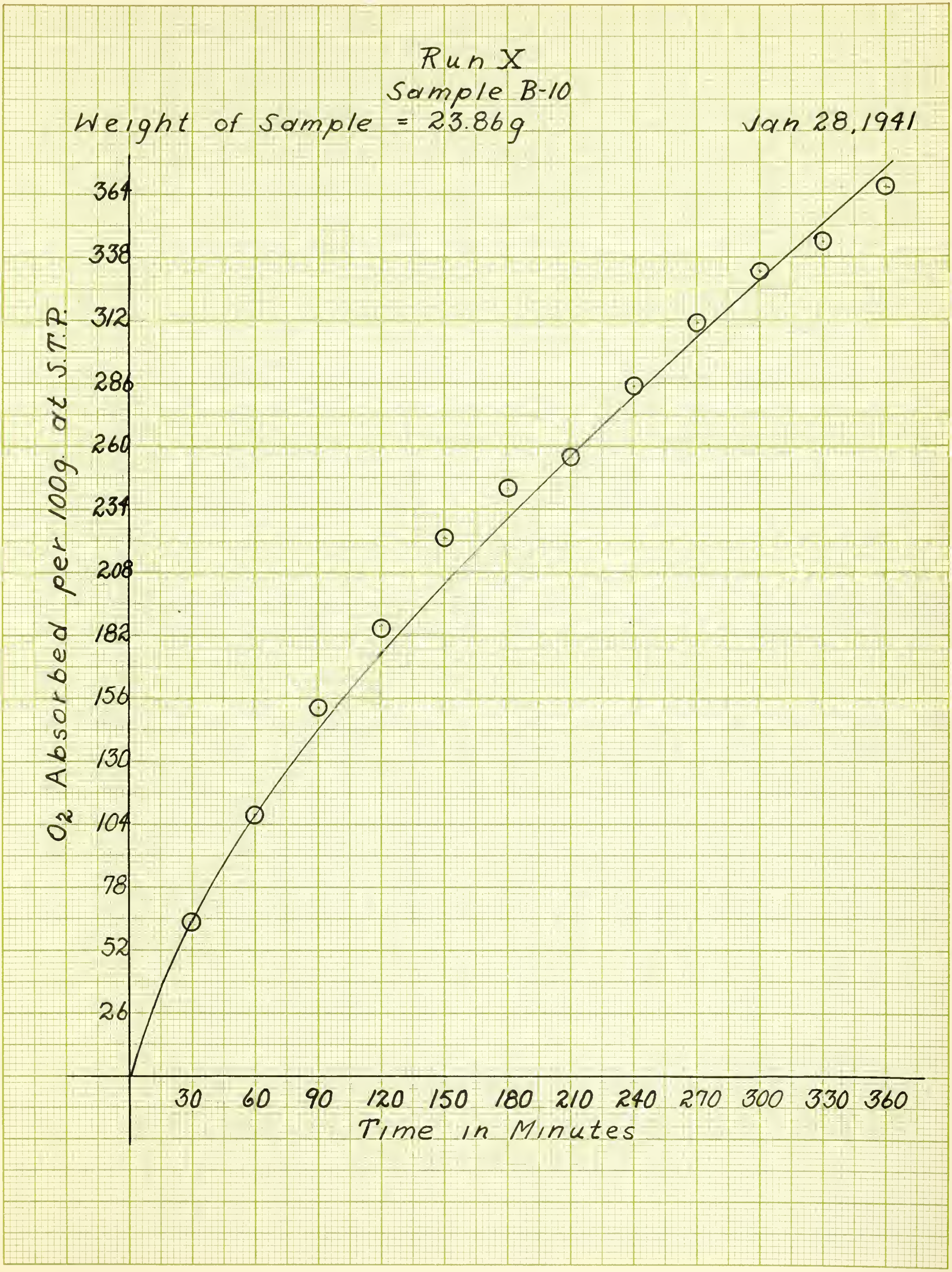


Run IX
Sample B-9
Weight of Sample = 26.15g

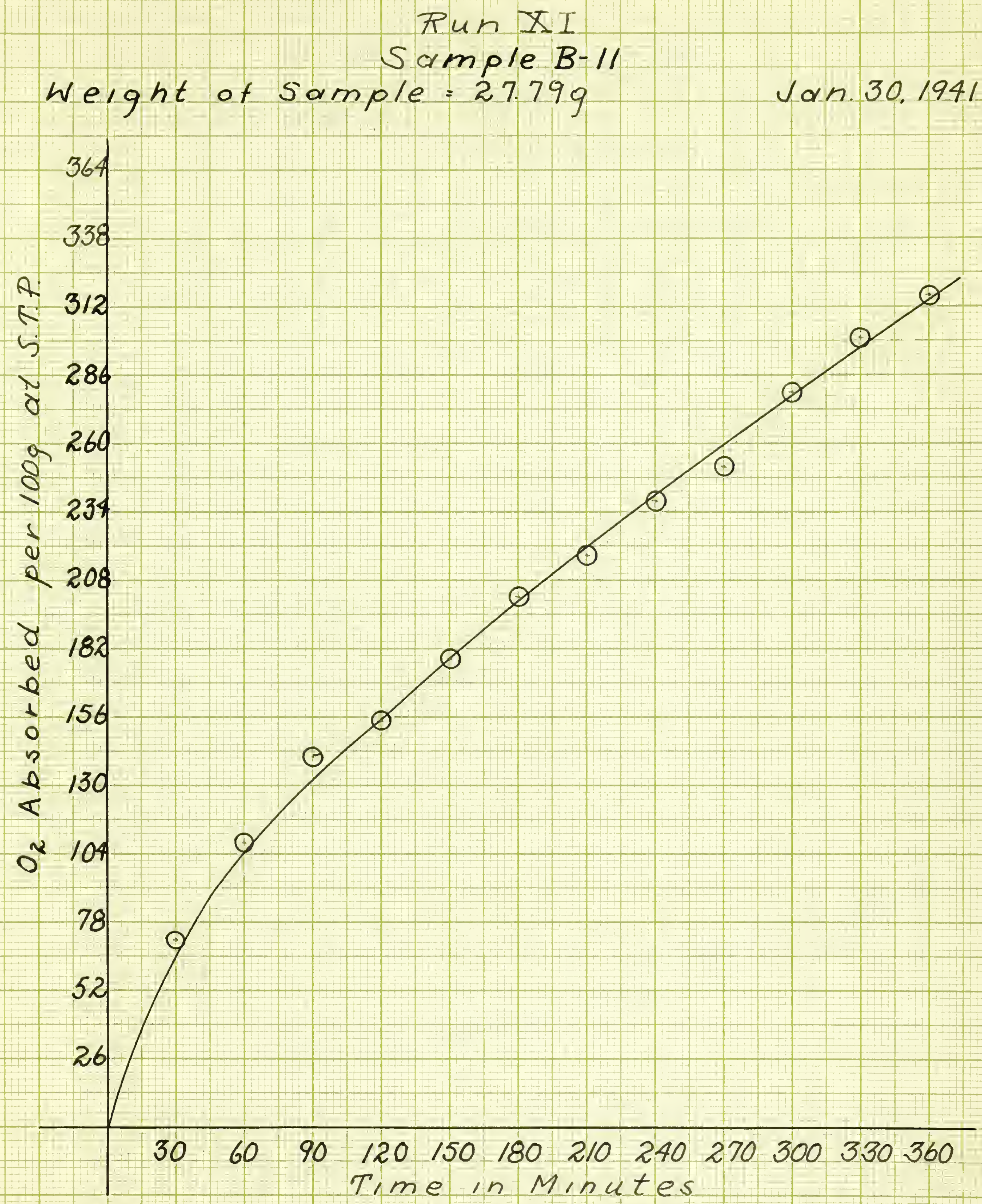
Jan. 22, 1941



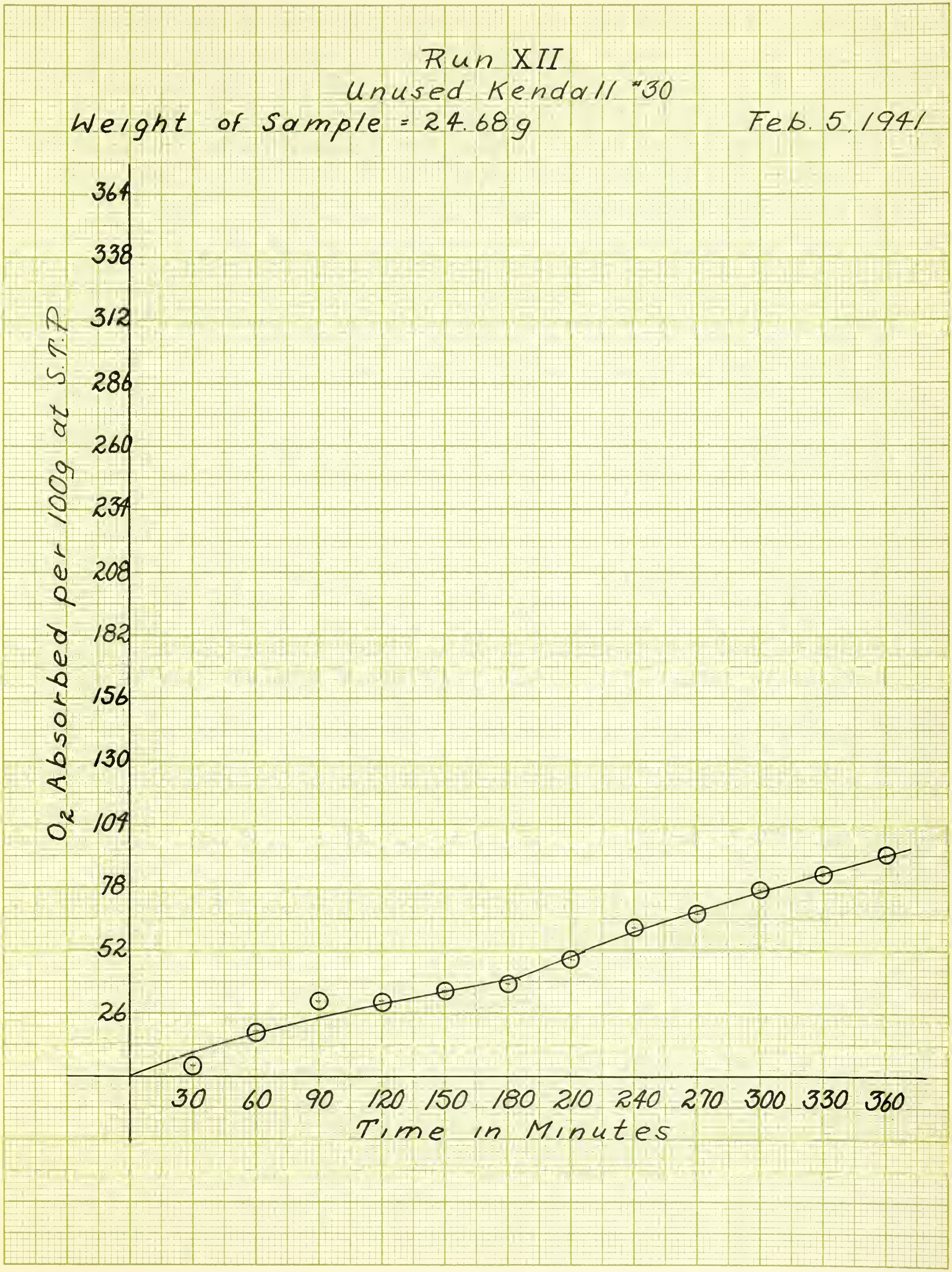
KEUFFEL & ESSER CO., N. Y. NO. 358-12
10 × 10 to the half inch, 10th lines heavy.
MADE IN U.S.A.

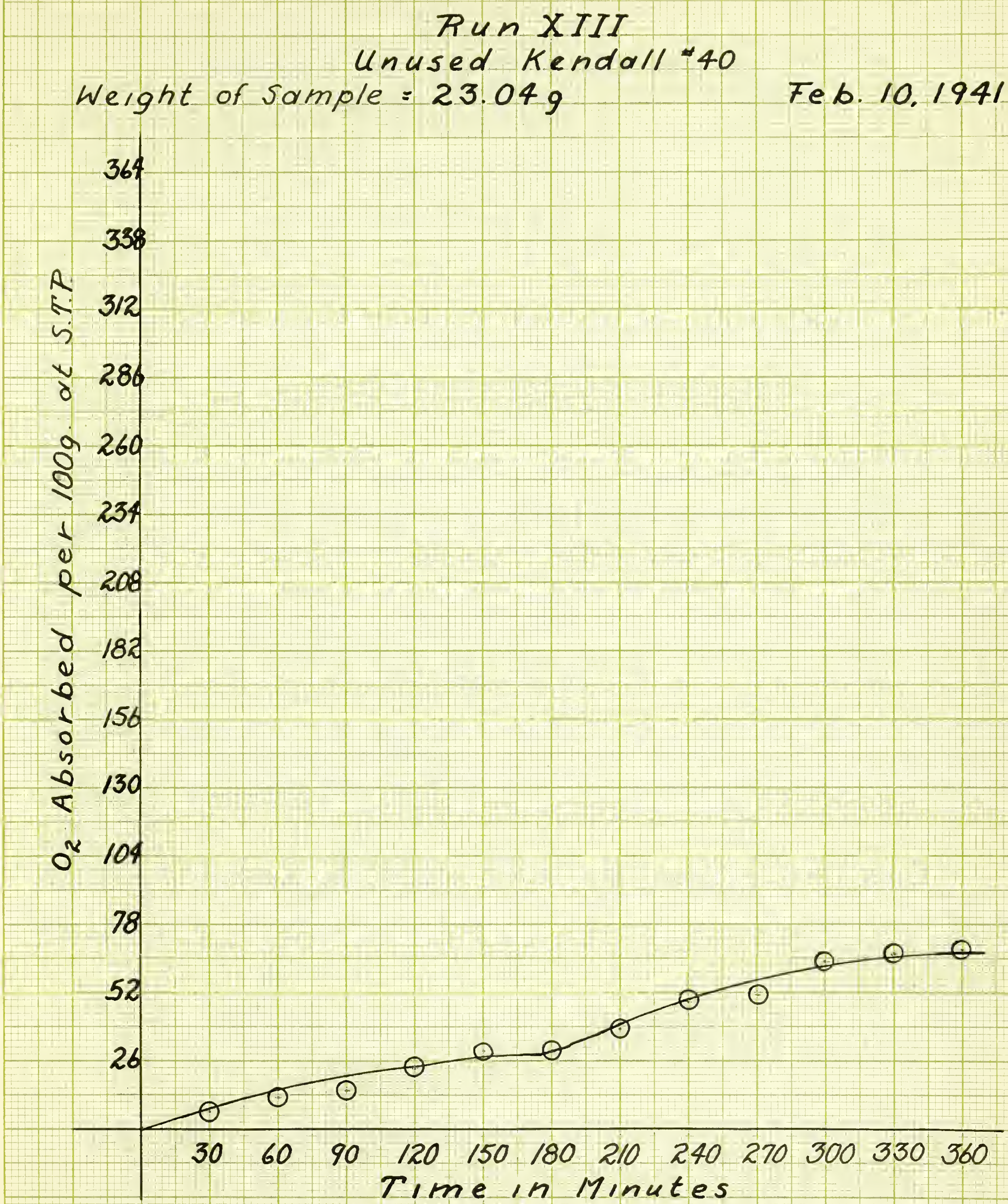


KEUFFEL & ESSER CO., N. Y. NO. 358-12
10 × 10 to the half inch, 10th lines heavy.
MADE IN U.S.A.



Run XI
Sample B-11
Weight of Sample = 27.79g
Jan. 30, 1941
O_2 Absorbed per 100g at S.T.P.
364
338
312
286
260
234
208
182
156
130
104
78
52
26
30
60
90
120
150
180
210
240
270
300
330
360
Time in Minutes


Run XII
Unused Kendall #30
Weight of Sample = 24.68g
Feb. 5, 1941
364
338
312
286
260
234
208
182
156
130
104
78
52
26
O_2 Absorbed per 100g at S.T.P.
30
60
90
120
150
180
210
240
270
300
330
360
Time in Minutes

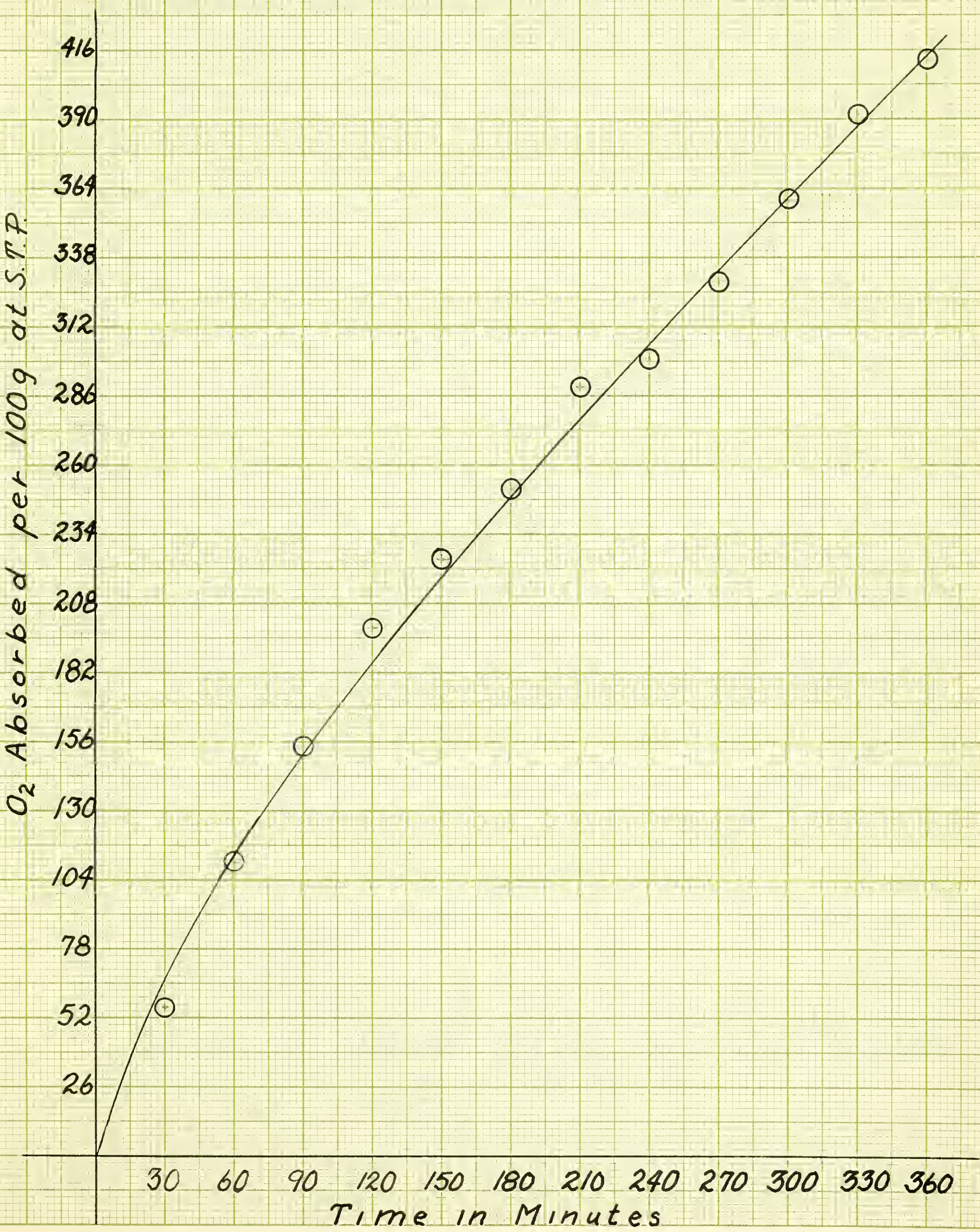


Run XIII
Unused Kendall #40
Weight of Sample = 23.04 g
Feb. 10, 1941
364
338
312
286
260
234
208
182
156
130
104
78
52
26
O_2 Absorbed per 100g. at S.T.P.
30
60
90
120
150
180
210
240
270
300
330
360
Time in Minutes

Run XIV

Sample B-9 with .025g. Hydroquinone

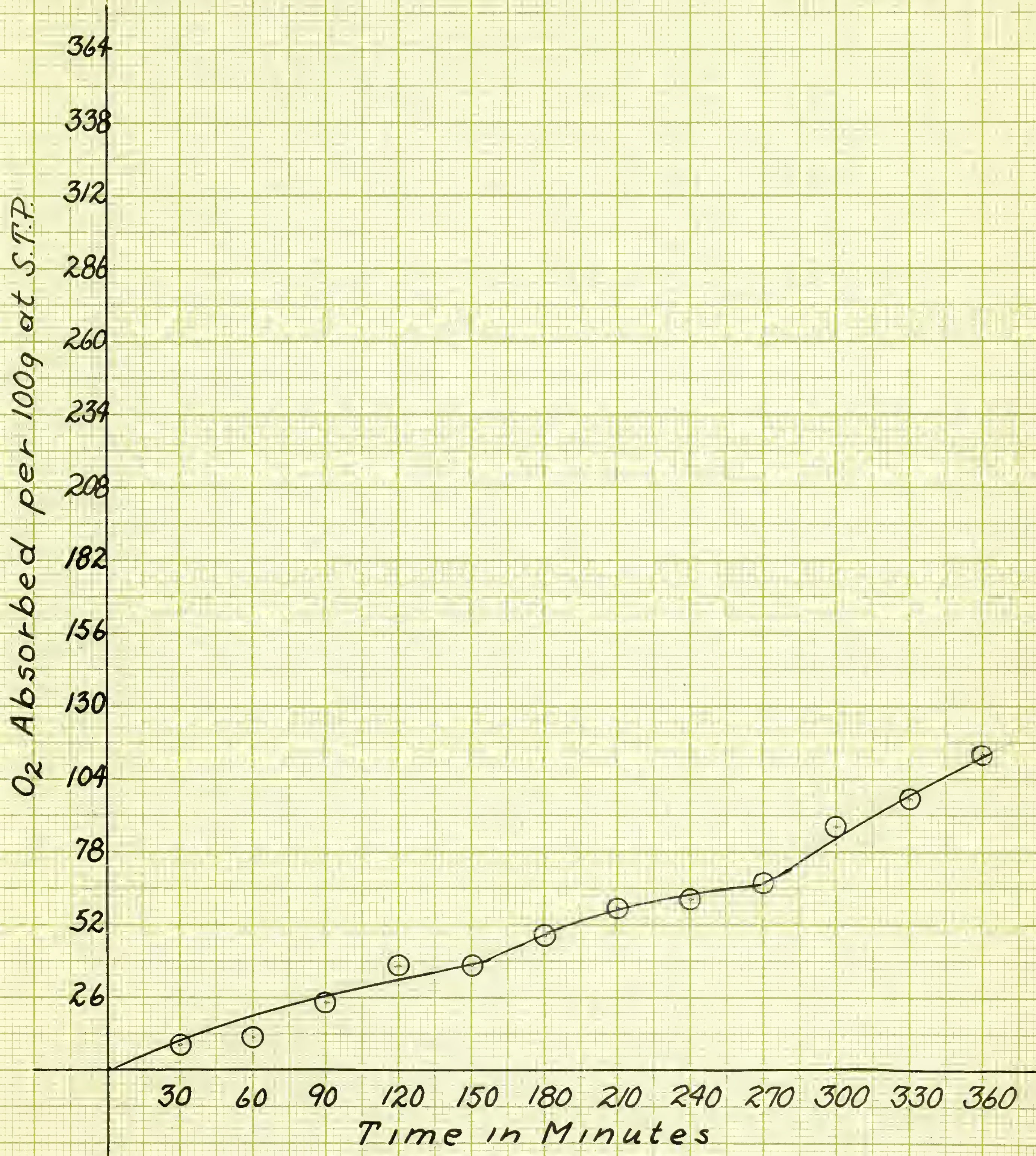
Weight of Sample = 25.63g　　　Feb. 11, 1941

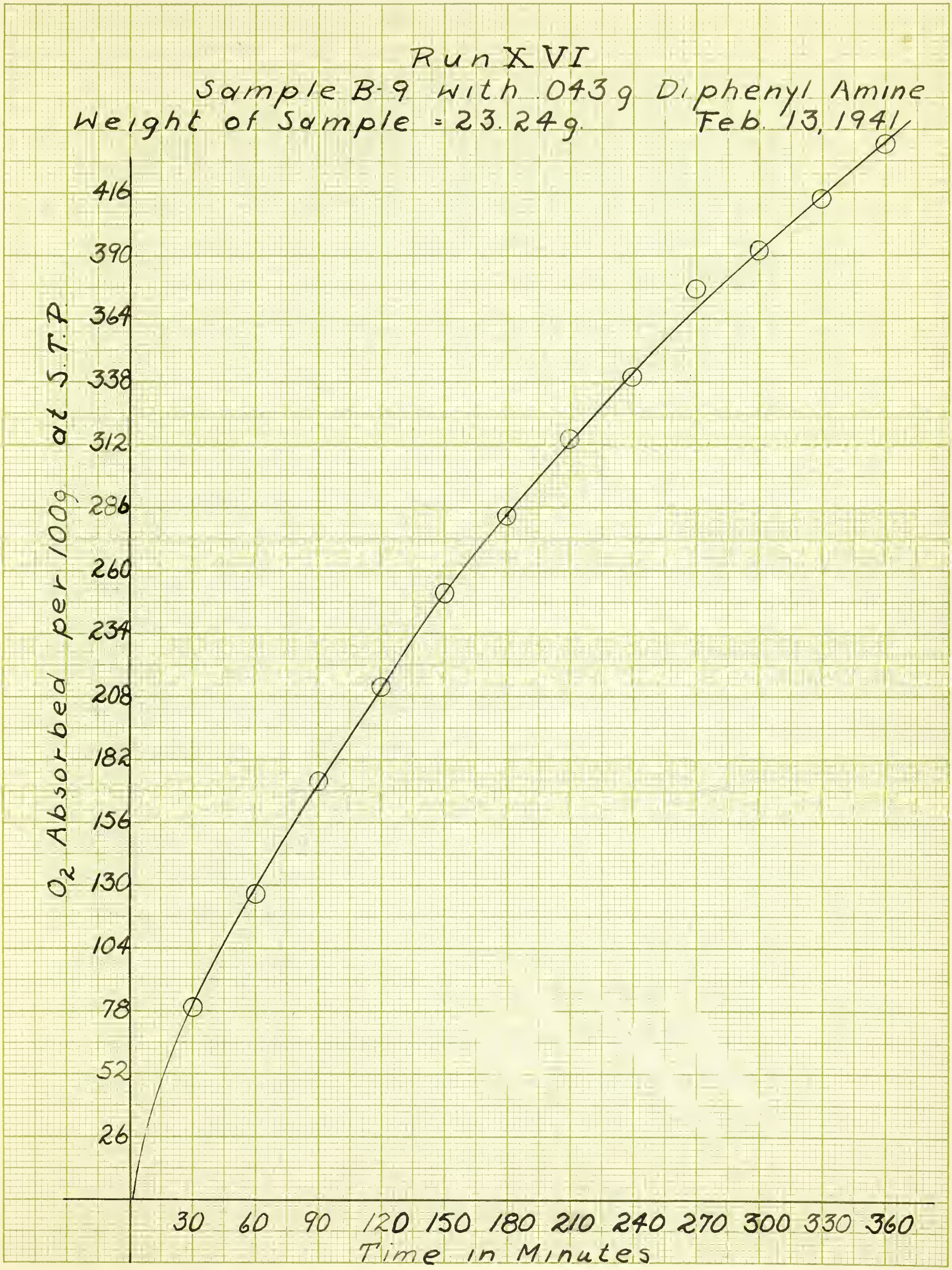


Run XV

Unused Quaker State #30

Weight of Sample = 23.99g. Feb. 12, 1941




Run XVI
Sample B-9 with .043 g Diphenyl Amine
Weight of Sample = 23.24g.
Feb. 13, 1941
O_2 Absorbed per 100g at S.T.P.
416
390
364
338
312
286
260
234
208
182
156
130
104
78
52
26
30
60
90
120
150
180
210
240
270
300
330
360
Time in Minutes

CONCLUSION

The results of this investigation have shown that the rate of oxidation of used crankcase oils is rapid at first and then gradually slopes off to an almost linear value with an increase in time. No direct correlation could be made between the rate of oxidation and the mileage that the oil was run. Nor could any correlation be made between the age of the sample and the rate of oxidation. It was shown that all the samples used absorbed oxygen from zero time and none showed a period of induction. The rate also showed that the used oils had lost their stability towards oxidation in comparsion to the new oils, which were more stable to oxidation under the conditions of these experiments.

The use of inhibitors of the type that have been investigated (3) shows that the rate of oxidation is increased by their addition which is in accordance with the theory already advanced. This theory states that once the oil has started to be oxidized the inhibitor used no longer acts as such. It actually increases the rate of oxidation. The two types of compounds used, Diphenyl Amine and Hydroquinone, were taken because they represented the extreme rates of inhibition of a series of compounds investigated (3). The Diphenyl Amine has shown by previous investigation to decrease the rate of oxidation for a period of five hours, while Hydroquinone only

(3) Kalichevsky, "Chemical Refining of Petroleum" Chapter X

for a period less than an hour. They were also chosen because they are easy to obtain in the pure state. The inhibitors used are substances that are easily oxidized, hence they would normally take up oxygen previous to the oil. In the case of a used oil where the amount of oxygen absorbed is almost four times as much as the unused sample, the inhibitor action has been and the rate increases as shown by curves XIV and XVI of this investigation.

If classes of compounds could be investigated other than those already tried (phenols and amines), it is the belief of the author that something could be found to decrease the rate of oxidation. This sustance would have to be more easily oxidized and of sufficiently high moleculear weight to use up all the oxygen taken up in a used sample of oil. It may be that some correlation may be made between the mileage that the oil was run and the type of an inhibitor used to decrease oxidation. Samples that absorbed the most oxygen were run approximately 3,000 miles. These were the samples tested for the effect of inhibitors. It might be that this distance was too great, and that a sample run 2,000 miles would give better results. These new theories should lead to further investigations towards the problem of improving used crankcase oils.